MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

ETM7136 – DIGITAL COMMUNICATION SYSTEMS AND DESIGN

(M.Eng.Tele)

22 OCTOBER 2019
2.30 p.m. – 5.30 p.m.
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of **7 printed pages** (including the cover page) with **4 questions only.**

2. **Attempt ALL questions.** All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.

Question 1

(a) Given that a signal $r(t) \leftrightarrow R(f) = \dfrac{1}{1+j2\pi f}$. Determine the Fourier transform for the signal $x(t) = 3r(1-t)$.

[5 marks]

(b) The Fourier transform of a signal $x(t)$ is $X(f) = \text{sinc}(f)$.

(i) Determine the autocorrelation function of $x(t)$.

[3 marks]

(ii) Sketch the autocorrelation function of $x(t)$.

[1 mark]

(c) The two sided power spectral density of a signal $w(t)$ is

$$W(f) = \begin{cases} 10^{-9} f^2, & -2100 \le f \le 2100 \\ 0, & \text{elsewhere} \end{cases}.$$

(i) Calculate the average normalized power of $w(t)$.

[2.5 marks]

(ii) If $w(t)$ is passed through an ideal lowpass filter with a cutoff frequency of 1.5 kHz, find the average normalized power of the waveform at the output of the filter and the percentage of signal's power lies in the frequency band passed by the filter.

[3.5 marks]

(d) Consider the signal $m(t) = 5e^{-2t}u(t)$, where $u(t)$ is the unit step function. Is $m(t)$ an energy signal or power signal? Justify your answer.

[5 marks]

(e) Consider that a 15 kbits/s data stream is to be transmitted on a voice-grade telephone line with a bandwidth of 2.9 kHz. Justify why it is not possible to obtain error-free transmission with a signal-to-noise ratio of 10 dB and propose two system modifications that might be made.

[5 marks]

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Question 2

(a) Figure Q2 shows the spectrum of an analogue message signal $m(t)$ that is bandlimited to $B = 10$ kHz.

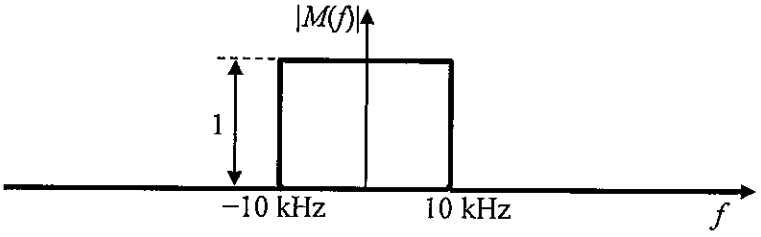

Figure Q2

The waveform is instantaneously sampled at f_s and passed through a holding network to produce a flat-top sampled signal. The spectral expression of the flat-top sampled signal is

$$M_\delta(f) = \tau f_s \left| \frac{\sin(\pi \tau f)}{\pi \tau f} \right| \sum_{k=-\infty}^{\infty} M(f - k f_s)$$

(i) Will aliasing occur if $f_s = 22$ kHz ? Justify your anwer. [2 marks]

(ii) Given that $f_s = 25$ kHz and $\tau = 10\mu s$, sketch $M_\delta(f)$. [4 marks]

(iii) State the main problem associated with the flat-top sampling? Suggest a method to overcome this problem. [2 marks]

(b) A speech signal is digitized using pulse code modulation (PCM) system. Assume that the speech signal is sampled at 8000 samples/s and the PCM encoded signal is to have an average signal-to-noise ratio (SNR) of at least 28 dB. Calculate the following:

(i) Minimum number of quantization levels that should be used. [3 marks]

(ii) Duration (in minutes) of PCM encoded speech data that can be stored on a 450 Mbyte hard disk. [2 marks]

(c) Explain the rationale of using adaptive delta modulation and its working principle in detail. [6 marks]

(d) Assume that quadrature phase shift keying (QPSK) modulation is used to transmit data at a bit rate of 44 Mbits/s over a channel with bandwidth of 30 MHz.

(i) If the overall equivalent transfer function is of the raised cosine type, calculate the roll-off factor required. [2.5 marks]

(ii) Using the obtained roll-off factor in Question 2(d)(i), calculate the minimum transmission bandwidth required if 16-PSK modulation is used to transmit data at the same bit rate of 40 Mbits/s. Deduce the percentage bandwidth saving as a result of this. [3.5 marks]

Continued...

Question 3

(a) Describe the main function of a matched filter at the receiver.

[2 marks]

(b) Consider a baseband binary communication system with equally likely signaling that transmits signals $s_i(t)$, where $i=1,2$. The receiver test statistic is given by $z(T)=a_i+n_0$, where the signal component a_i is either $a_1=+1$ or $a_2=-1$ and the probability distribution function (pdf) of the noise component n_0 is given by the triangular function as shown in Figure Q3. Evaluate the probability of a bit error if the decision threshold is 0V.

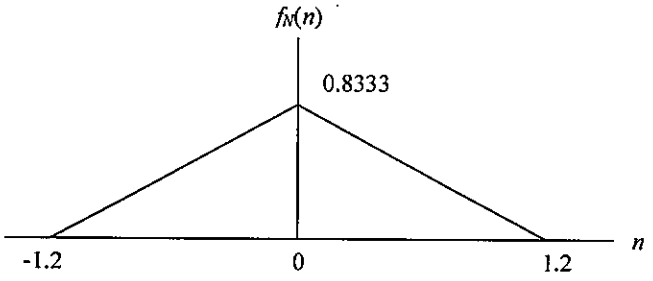

Figure Q3

[4 marks]

(c) With the aid of signal diagrams, describe the distinctive features of offset quadrature phase shift keying (OQPSK) signals as compared to QPSK signals using rectangular pulses. Explain the main advantages of OQPSK over QPSK.

[6 marks]

(d) Orthogonal Frequency-Division Multiplexing (OFDM) is a digital multi-carrier modulation scheme.

(i) With the aid of diagrams, describe the working principle of OFDM and explain how intersymbol interference can be mitigated using an OFDM modulation scheme.

[7 marks]

(ii) Explain the role of virtual carriers in OFDM.

[2 marks]

(e) With the aid of diagram, explain the working principle of concatenated codes.

[4 marks]

Continued...

Question 4

(a) Consider a Hamming (7,4) code with the following parity-check matrix **H**.

$$\mathbf{H} = \begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

(i) Calculate the code rate and redundancy of this Hamming code.

[3 marks]

(ii) Obtain its generator matrix **G**.

[2 marks]

(iii) Determine the Hamming weight of the codeword produced by the message 1001.

[2.5 marks]

(iv) Compute the syndrome for the received vector 1110111 and determine if an error has occured. If it has, find the correct codeword.

[2.5 marks]

(b) Consider the following impulse responses for the paths of a convolutional encoder.

$$g^{(1)} = (1, 0, 1)$$
$$g^{(2)} = (1, 1, 1)$$
$$g^{(3)} = (1, 1, 1)$$

(i) Give the corresponding generator polynomials for the impulse responses above.

[3 marks]

(ii) Design the encoder circuit for this convolutional code.

[3 marks]

(iii) Sketch the state-transition diagram.

[3 marks]

(iv) Determine the codeword that corresponds to the information sequence 10101.

[1 mark]

(c) Trellis coded modulation (TCM) combines convolutional encoding with modulation.

(i) Explain the key idea behind this integrated coding and modulation approach.

[2 marks]

(ii) List down three main features of a TCM system.

[3 marks]

Continued...

Appendix I: Fourier Transform Pairs

Pair Number	$x(t)$	$X(f)$
1.	$\Pi\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc} \tau f$
2.	$2W \operatorname{sinc} 2Wt$	$\Pi\left(\frac{f}{2W}\right)$
3.	$\Lambda\left(\frac{t}{\tau}\right)$	$\tau \operatorname{sinc}^2 \tau f$
4.	$\exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{\alpha + j2\pi f}$
5.	$t \exp(-\alpha t)u(t),\ \alpha > 0$	$\frac{1}{(\alpha + j2\pi f)^2}$
6.	$\exp(-\alpha\|t\|),\ \alpha > 0$	$\frac{2\alpha}{\alpha^2 + (2\pi f)^2}$
7.	$e^{-\pi(t/\tau)^2}$	$\tau e^{-\pi(f\tau)^2}$
8.	$\delta(t)$	1
9.	1	$\delta(f)$
10.	$\delta(t - t_0)$	$\exp(-j2\pi f t_0)$
11.	$\exp(j2\pi f_0 t)$	$\delta(f - f_0)$
12.	$\cos 2\pi f_0 t$	$\frac{1}{2}\delta(f - f_0) + \frac{1}{2}\delta(f + f_0)$
13.	$\sin 2\pi f_0 t$	$\frac{1}{2j}\delta(f - f_0) - \frac{1}{2j}\delta(f + f_0)$
14.	$u(t)$	$(j2\pi f)^{-1} + \frac{1}{2}\delta(f)$
15.	$\operatorname{sgn} t$	$(j\pi f)^{-1}$
16.	$\frac{1}{\pi t}$	$-j \operatorname{sgn}(f)$
17.	$\hat{x}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{x(\lambda)}{t - \lambda} d\lambda$	$-j \operatorname{sgn}(f) X(f)$
18.	$\sum_{m=-\infty}^{\infty} \delta(t - mT_s)$	$f_s \sum_{m=-\infty}^{\infty} \delta(f - mf_s),$ $f_s = T_s^{-1}$

Continued...

Appendix II: Fourier Transform Properties

Name of Theorem		
1. Superposition (a_1 and a_2 arbitrary constants)	$a_1x_1(t) + a_2x_2(t)$	$a_1X_1(f) + a_2X_2(f)$
2. Time delay	$x(t - t_0)$	$X(f)e^{-j2\pi ft_0}$
3a. Scale change	$x(at)$	$\lvert a\rvert^{-1}X\left(\frac{f}{a}\right)$
b. Time reversal	$x(-t)$	$X(-f) = X*(f)$
4. Duality	$X(t)$	$x(-f)$
5a. Frequency translation	$x(t)e^{j\omega_0 t}$	$X(f - f_0)$
b. Modulation	$x(t)\cos\omega_0 t$	$\frac{1}{2}X(f - f_0) + \frac{1}{2}X(f + f_0)$
6. Differentiation	$\frac{d^n x(t)}{dt^n}$	$(j2\pi f)^n X(f)$
7. Integration	$\int_{-\infty}^{t} x(t')\,dt'$	$(j2\pi f)^{-1}X(f) + \frac{1}{2}X(0)\delta(f)$
8. Convolution	$\int_{-\infty}^{\infty} x_1(t - t')x_2(t')\,dt'$	$X_1(f)X_2(f)$
	$= \int_{-\infty}^{\infty} x_1(t')x_2(t - t')\,dt'$	
9. Multiplication	$x_1(t)x_2(t)$	$\int_{-\infty}^{\infty} X_1(f - f')X_2(f')\,df'$
		$= \int_{-\infty}^{\infty} X_1(f')X_2(f - f')\,df'$

End of Paper